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Piston Vacuum Pump

The invention relates to a piston vacuum pump with a gas inlet in a cylinder side wall.

In piston vacuum pumps and in small piston vacuum pumps with a pumping output of less than 4 m^3/h in particular, the construction of the gas inlet and the dead volumes associated therewith play a great part for the structural size and the efficiency of the pump, respectively. Since the gas inlet cannot be arranged in the region of the cylinder bottom for lack of structural space, particularly in small vacuum pumps, the gas inlet is arranged in a side wall. Such a piston vacuum pump is described in DE 196 34 517. For balancing the pressure at the beginning of the intake stroke, an equalizing conduit is provided between the exhaust and the compression chamber, the mouth of the equalizing bore being arranged in the compression chamber near the cylinder bottom. In the course of the equalizing conduit, a non-return valve is arranged which needs structural space. The non-return valve is not arranged in the cylinder wall plane so that a dead volume degrading the efficiency is formed in the equalizing conduit.

Against this background , it is an object of the invention to provide an improved piston vacuum pump with a gas inlet in the cylinder side wall.

This object is solved, according to the invention, with the features of claim 1.

According to the invention, the piston substantially forms the equalizing conduit and the valve. This is to mean that the piston forms the equalizing conduit and the valve at least partially, but not necessarily alone. Since the equalizing conduit is formed by the piston, the equalizing conduit does not require any space in the region of the cylinder bottom or the cylinder side. A compact construction of the cylinder is made possible thereby. The valve is also formed substantially by the piston so that the valve effect is produced at the piston end wall or in the immediate neighborhood of the piston end wall. Thereby, a dead volume outside the cylinder chamber is avoided so

that the efficiency of the pump is not degraded. The equalizing conduit and the valve can be formed by the piston in different ways. The valve can be configured as a mechanical non-return valve but also as a gas throttle. The equalizing conduit can be formed by the piston only, but also by the piston and the cylinder in common.

According to a preferred embodiment, the equalizing conduit is formed in the piston between a piston end wall opening and a piston bottom wall opening, the piston side wall opening and the gas inlet being connected with each other at the beginning of the intake stroke. Hence, at the beginning of the intake stroke, there exists a connection from the gas inlet to the compression chamber although the piston is still at the level of the gas inlet and does not permit a direct escape of gas from the gas inlet into the compression chamber.

Preferably, the valve is a non-return valve blocking in the direction of the gas inlet and opening in the direction of the compression chamber. Thereby, a reflux of compressed gas via the equalizing conduit is prevented during the compression stroke. The non-return valve may be arranged in the plane of the piston end wall so that the dead volume practically equals zero.

According to a preferred embodiment, the gas inlet has an annular groove in the cylinder side wall and/or in the piston side wall allocated thereto. Thereby, an enlargement of the gas inlet is effected or, if the piston is not guided, a gas transfer between cylinder and piston is made possible in any rotational position of the piston. The annular groove may also be enlarged in axial extension with respect to the gas inlet to extend the gas entry during the intake stroke.

Preferably, the equalizing conduit and the valve are formed by a gap between the piston side wall and the cylinder side wall, the gap width ranging between 10 to 100 µm. The equalizing conduit and the valve are thus de-

fined by the piston side wall and the cylinder side wall. The gap width is selected such that a sufficient gas flow occurs between the gas inlet and the compression chamber during the intake stroke, the gas flow from the compression chamber to the gas inlet during the compression stroke, however, is so small that it does not substantially degrade the efficiency of the pump. The gap between the piston side wall and the cylinder side wall is an equalizing conduit and a valve at the same time. This is guaranteed with gap widths of 10 to 100 µm, the gap width being required to be below 50 µm with differential pressures of more than 100 mbar.

Preferably, a storage chamber is provided in the course of the equalizing conduit in the piston. With a piston position about the dead center between intake stroke and compression stroke, the storage chamber is filled so that a pressure compensation between the storage chamber and the compression chamber can be effected by the piston end wall directly at the beginning of the intake stroke while the gas inlet is simultaneously closed.

Preferably, the equalizing conduit and the valve are formed by a substantially axial groove in the piston side wall or in the cylinder side wall. The groove may extend axially, but may also be formed obliquely in the form of a helical line in the piston side wall or the cylinder side wall. Thus, an equalizing conduit is also formed which does not need any mechanical elements and can be produced easily. The valve effect results from a corresponding selection of the cross section of the groove which is selected such that a sufficient pressure compensation is guaranteed during the intake stroke, but no reflux losses occur during the compression stroke which are too great.

According to a preferred embodiment, the valve is configured as a throttle. This means that the valve is implemented without any movable parts, whereby a high reliability is achieved and low manufacturing costs are realized.

Hereinafter, several embodiments of the invention are explained in detail with reference to the drawings.

In the Figures:

Fig. 1 shows a first embodiment of a piston vacuum pump with an equalizing conduit and a valve arranged in the piston and in the dead center of the piston between the compression stroke and the intake stroke,

Fig. 2 shows the piston vacuum pump of Figure 1 during the intake stroke,

Fig. 3 shows a second embodiment of the piston vacuum pump with a circumferential gas inlet groove,

Fig. 4 shows a third embodiment of the piston vacuum pump with a circumferential gas inlet groove in the piston side wall,

Fig. 5 shows a fourth embodiment of the piston vacuum pump with a gap between the piston side wall and the cylinder side wall, which forms the equalizing conduit and the valve, and

Fig. 6 shows a fifth embodiment of a piston vacuum pump where the equalizing conduit and the valve are formed by an axial groove in the piston side wall.

Figures 1-6 respectively show a piston-cylinder arrangement 10,50,60,70,80 of a piston vacuum pump where substantially only the region of the piston and the cylinder is shown but not the piston drive.

The illustrated piston vacuum pumps can be of a single-stage configuration, i.e., with a single piston and a single cylinder, the vacuum pump, however,

may also be formed with two pistons formed by a piston body which form two compression chambers. The compression chambers may be connected in series to form a two-stage piston vacuum pump but may also be connected in parallel. They are piston vacuum pumps with a small pumping volume, i.e., with a pumping volume of less than 4.0 m;/h and a piston and cylinder diameter of less than 50 mm, respectively.

The piston-cylinder arrangement 10 of the Figures 1 and 2 is substantially formed by a piston 12 with a circular cross section which is arranged in a circular cylinder 14 so as to be movable in axial direction. The piston-cylinder arrangement 10 is constructed so as to be symmetrical to a transverse plane so that a single piston body forms two pistons 12,12'. Both pistons 12,12' as well as the two cylinders 14 associated therewith are configured to be mirror-inverted to the central transverse plane.

The cylinder 14 is substantially formed by a cylinder side wall 16 and a cylinder discharge valve 18 forming the cylinder bottom. The cylinder discharge valve 18 is formed by a plane valve disk 20 and a compression spring 22 that biases the valve disk 20 in its closing position.

The piston 12 is a hollow body and comprises a cylindrical piston side wall 24 and a plane piston end wall 26. The piston 12 oscillates in the cylinder 14 between two dead centers between an intake stroke and a compression stroke and a compression stroke and an intake stroke, respectively. The dead center between a compression stroke and an intake stroke is illustrated in Figure 1.

In the cylinder side wall 24, two gas inlets 30 are provided which are axially spaced from the cylinder bottom, i.e., from the valve disk 20, to a specified extent. As illustrated in Figure 2, the two opposite gas inlets 30 are spaced so far from the cylinder bottom that they are closed by the piston during the intake stroke and the compression stroke as long as the piston has not

reached its dead center between the intake stroke and the compression stroke. Only in this dead center has the piston 12 completely passed the gas inlets 30 with its piston end wall 26 so that the gas from the gas inlets 30 can directly flow into the compression chamber 28 formed by the piston 12 and the cylinder 14. As soon as the piston 12 starts the compression stroke, it closes the gas inlets 30 with its piston side wall 24 again.

In its side wall 24, the piston 12 comprises two piston side wall openings 32 opening into a piston cavity forming a storage chamber 34. In the axial center of the piston end wall 26, an end wall opening 36 is provided which, together with a spring tongue 38 mounted at the outside of the end wall 26, forms a non-return valve 40. The non-return valve 40 opens as soon as the gas pressure in the piston storage chamber 34 lies above the gas pressure in the compression chamber 28. This happens in the intake stroke of the piston 12 illustrated in Figure 2 so that a pressure compensation between the storage chamber 24 and the compression chamber 28 occurs during the intake stroke. During the compression stroke of the piston 12, the non-return valve 40 stays closed.

The piston-cylinder arrangement 10 operates as follows:

During the compression stroke of the piston 12, the non-return valve 40 is closed and the gas in the compression chamber 28 is compressed. As soon as the gas pressure in the compression chamber 28 reaches the exhaust pressure, the cylinder discharge valve 18 opens and flows out of the compression chamber 28. At the end of the compression stroke of the piston 12, the piston reaches the dead center illustrated in Figure 1. In this piston position, the two gas inlets 30 are in alignment with the piston side wall openings 32 so that a pressure compensation occurs and gas flows into the storage chamber 34. Upon this, the intake stroke illustrated in Figure 2 starts. The gas inlets 30 and the side wall openings 32 are no longer in alignment with each other so that no gas can flow on into the storage chamber 34. As

soon as the gas pressure in the compression chamber 28 falls considerably below the gas pressure in the storage chamber 34, the non-return valve 40 opens so that gas flows from the storage chamber 34 into the compression chamber 28. Thereby, a strong negative pressure in the compression chamber 28 is avoided during the intake stroke so that the driving power required therefor is relatively small. At the end of the intake stroke and upon reaching the dead center terminating it, the piston 12 does not close the gas inlet 30 any more so that gas flows directly from the gas inlet 30 into the compression chamber 28. At the beginning of the compression stroke to the end of the intake stroke, the piston 12 again closes the gas inlets 30 with respect to the compression chamber 28. During the following compression stroke, the non-return valve 40 is closed again.

In the embodiment illustrated in Figure 3, a single gas inlet 30 is provided which opens into an annular groove 52. The annular groove 52 extends circumferentially and is let into the cylinder side wall 16. In Figure 4, a similar piston-cylinder arrangement 60 is illustrated where, in contrast to the embodiment of Figure 3, an annular groove 62 is let into the cylinder side wall 24. The annular grooves 52,62 axially extend over a multiple of the width of the gas inlet 30. Thereby, a connection between the gas inlet 30 and the piston storage chamber 34 still exists during the intake stroke of the piston 12 illustrated in Figures 3 and 4.

The piston side wall openings 32 and the piston storage chamber of the piston-cylinder arrangements of Figures 1-4 form an equalizing conduit for compensating the (negative) pressure in the compression chamber 28 during the intake stroke of the piston 12.

In the piston-cylinder arrangements 70,80 illustrated in Figures 5 and 6, the configuration of the equalizing conduit has a configuration that is different from that of the piston-cylinder arrangements 10,50,60 of Figures 1-4.

In the piston-cylinder arrangement 70 of Figure 5, the equalizing conduit is configured as a gap 72 between the side wall 73 of the piston 74 and the side wall 75 of the cylinder. The gap 72 has a gap width of about 50 μm. The gap width, however, may also be larger or smaller and depends on how great the pressure differences between the gas inlet 30 and the compression chamber 28 are. Because of its throttling effect, the gap 72 also forms a valve so that the gap 72 forms the equalizing conduit as well as the valve. The gap width is selected to be so small that the reflux losses during the compression stroke of the piston 74 are as small as possible. The gap width, however, is selected to be so large that a certain pressure compensation takes place between the gas inlet 30 and the compression chamber 28 during the intake stroke.

In the embodiment of a piston-cylinder arrangement 80 illustrated in Figure 6, the equalizing conduit and the valve are configured as an axial groove 82 in the piston side wall 84. Alternatively, the equalizing conduit and the valve may also be configured as an axial groove in the cylinder side wall.

The cross section of the axial groove 82 is selected such that during the intake stroke of the piston 86, a sufficient pressure compensation occurs between the gas inlet 30 and the compression chamber 28, but the reflux losses between the compression chamber 28 via the groove 82 into the gas inlet 30 during the compression stroke of the piston 86 are small.